Maglev Technology

Teacher's Handbook - Activities On Electromagnetism & Magnetism

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Teacher's Handbook: Activities On Electromagnetism & Magnetism

by
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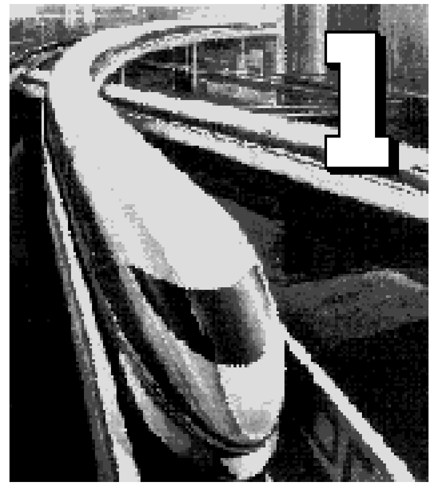


Flying on magnets!

Imagine **floating 12 centimeters off the ground** while traveling at **500 kilometers an hour**! There is no sound of steel wheels banging into steel rails, no humming of motors, just the sound of the air rushing by! Computers automatically control your speed and position. Is this possible? Yes, this is Maglev!

Maglev is short for **magnetically levitated vehicle**. A Maglev vehicle floats on and is moved forward by forces from magnets. When the vehicle is levitating it doesn't touch the ground and doesn't need wheels. **Argonne National Laboratory**, a U.S. Department of Energy research facility, has been involved in the theoretical and experimental work on Maglev for the past three years. Other government agencies are also involved in Maglev research. If Congress and business leaders provide enough money, a U.S.-built Maglev will fly through many U.S. cities in the next 10 or 15 years.

Maglev saves time, money, energy and the environment!!

Maglev can travel at 500 kilometers per hour. Current high speed rolling trains can only reach about 308 kilometers an hour. High speed trains have achieved higher speeds in test runs, but it is very difficult for them to go that fast all the time. For example, there is a lot of wear and tear on the moving parts and the rails have to be straightened out quite often or else the train could fall off the track! (Later it will be shown why Maglev can't fly off its guideway!)

How does Maglev compare to airplanes? Well, 500 km or 300 miles per hour is about half the speed of passenger airplanes. So, how can Maglev save time compared to an airplane? Many of **today's airports are very busy**, and that means passengers often spend a lot of time waiting at the airport. Airplanes have to taxi out to the runway and wait until one is clear for takeoff. Also, if the weather is bad, airplanes can't fly. **On Maglev, passengers won't have to wait** for empty runways or because of bad weather. On Maglev you just get in, sit down and you're on your way! What if the weather is icy? Maglev floats right over the ice while an airplane is still waiting for the runway to be plowed. In addition, Maglev can go from the center of one city to the center of another. This means that the passenger saves time by not having to travel to the airport, because most airports are on the outskirts of cities.

Saving time means saving money. Getting there more quickly saves money for the airports and for the passengers. It means that business people can get to meetings in other cities sooner, and get more work done. It means that vacationers can have more time to enjoy themselves.

Maglev uses 1/3 the energy of airplanes! Conserving energy means using up fewer natural resources and creating **less pollution**. Maglev runs on electricity. It is easier to control pollution at power plants where electricity is generated than it is to control pollution from airplanes. Also, using electricity instead of oil means that the U.S. won't have to rely on foreign countries for oil.

PROPERTIES OF MAGNETISM

Science Activity 1.1 Floating Discs

Objective: To demonstrate repulsive force of magnets

Materials:

• Six or eight small disc magnets or ring magnets

• A test tube (for the discs) or a pencil in a one-hole stopper (for the rings).

Procedures:

1. Stick the magnets together two by two.
2. Slide the first pair in the bottom of the test tube.
3. Slide the second pair in the tube, such that they repel the first pair. (If they are attracted to the first pair, take all four out, turn the two upper discs upside down and slide them back in the tube).
4. Do the same with the next two pairs of disc magnets.
5. If ring magnets are used: slide them around the pencil, such that they repel each other.

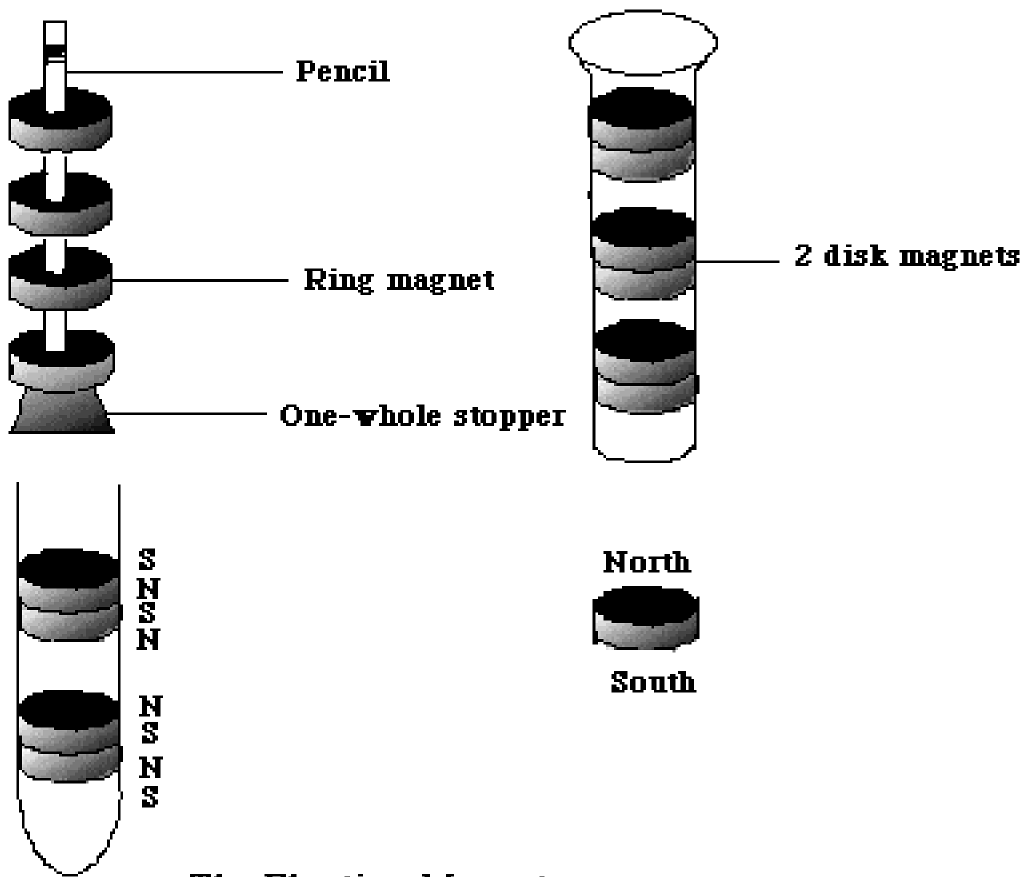
Assessment and Review:

1. Why do the pairs of discs stick together?
2. Where would the poles of the disc magnets be located?
3. Assign a letter N or S for each of the poles.
4. How could we get the discs out of the test tube without turning the tube upside down?

Explanation:

The pairs of discs have unlike poles facing each other and therefore they attract each other. The poles of the disc magnets are located at their two circular paths, and the 'floating' occurs because the same poles face and thus repel each other. If the bottom pole is assigned to be North, the other poles have to be in the order as in the sketch on the bottom, in order to get the 'floating' pair arrangement.

The same can be done with the ring magnets.



The Floating Magnets

Science Activity 1.2 Maglev Trains

Objective: To research available material on maglev trains

Material: School library

Procedure:

Trains that float on air have been under development for many years. These are trains without wheels that are suspended by a magnetic field. A linear induction motor propels the floating cars. The first commercial magnetic levitation (maglev) train is now in operation connecting the Birmingham, England airport with a railroad station about a quarter of a mile away.

Assessment and Review:

Using your school library, research maglev trains and answer the following questions.

1. When was development of maglev trains started and in what country?

2. How does magnetism keep the cars suspended?

3. What are the top speeds of maglev trains?

4. How safe are these trains?

5. What features make maglev trains economical?

6. What other advantages do maglev trains have?

EMPLOYING MAGNETIC FORCE

Science Activity 1.3 The Floating Paper Clip

Objectives: To demonstrate the attractive force of magnets

Materials:

• A rod magnet, stand and clamp.

• A paper clip and thread (transparent or black), tape, scissors

Procedures:

1. Clamp a rod magnet vertically and tape a cardboard sign, “The Floating Paper Clip” in front of it. (The bottom edge should be flush with the magnet.)
2. Tie a paper clip to a thread and tape the other end of the thread to the base of the stand, such that the clip is still held up by the magnet, but leaving a gap between the two.
3. Show to students that no thread is holding the clip up by sliding thin objects through the gap. (A ruler, a card, a comb, etc.)
4. Take a pair of scissors and cut the magnetic lines that are holding the paper clip up.

Assessment and Review:

1. What materials could you slide through the gap without making the paper clip fall?
2. What materials will definitely “cut” the magnetic field?
3. Which coins will go through the gap without causing the clip to drop?

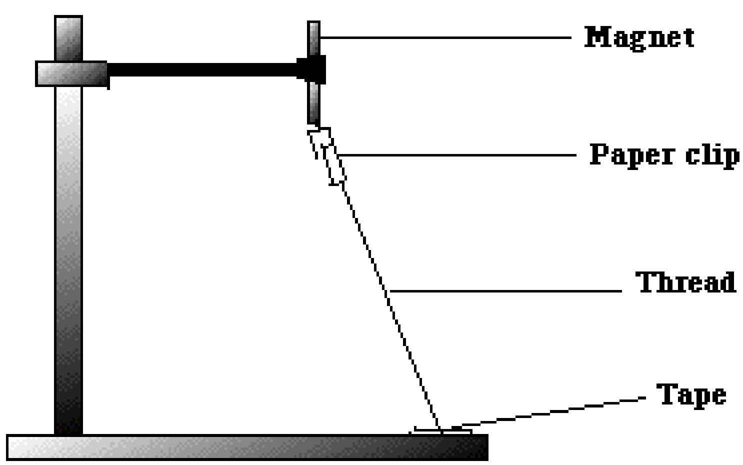
4. Why do only some dimes (old ones) pass the gap without “cutting” the magnetic lines?

5. What were the scissors actually doing to the magnetic lines?

Extension, reinforcement, or optional activity:

The paper clip is held up by **magnetic lines** indeed. When the magnetic lines are prevented from going through the clip, it falls. Materials that can absorb the magnetic lines from the magnet are materials which are iron, nickel, and cobalt or contain any amount of it (for example, an alloy).

Magnetism originates from within the atom. In the magnetic materials: iron, nickel and cobalt, the electrons around the nuclei, although paired together do not completely cancel out the magnetic fields. They could be considered as consisting of minute magnets that are randomly arranged. When these minute magnets are all lined up in one direction, the object can become a strong magnet.



Floating Paper Clips

Science Activity 1.4 The Maglev Pencil

Objective: To demonstrate the repulsive forces of magnets

Materials:

• Pencil, masking tape

• 6 Ring magnets, clay

• Glass or plastic slide

• Small block of wood

• Cardboard (about 10 x 25 cm)

Procedures:

1. Wrap masking tape smoothly around the pencil about 3cm from each end. Add enough tape to fit a ring magnet firmly on the pencil.
2. Fit a ring magnet over the masking tape on each end of the pencil.
3. Using the clay, arrange the four remaining magnets on the cardboard as shown in the diagram.
4. Position each magnet so that it repels the one at that end of the pencil.
5. Tape the slide to the wood block as shown in the diagram.
6. Place the wood block on the cardboard as shown and position the pencil over the four lower magnets.
7. Experiment with the position of the wood block until the pencil will levitate with only the pencil point touching the slide.

Assessment and Review:

1.What causes the pencil to float?

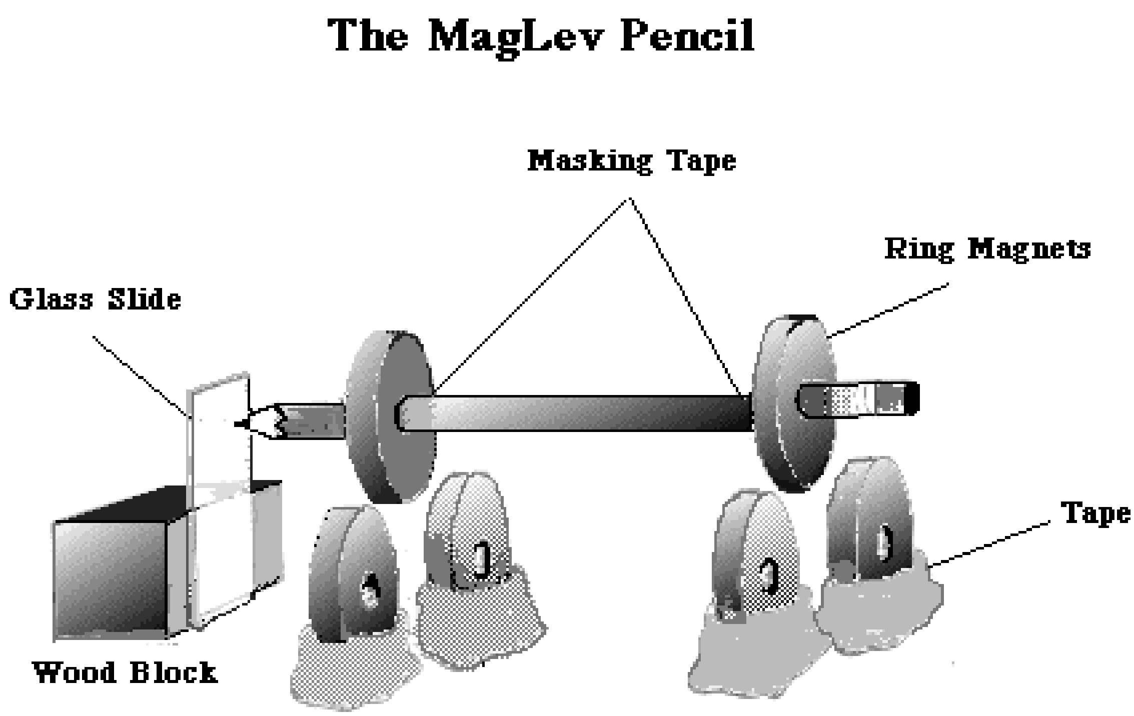
2. How long could you get the pencil to spin?

3. Why is the block of wood and slide necessary?

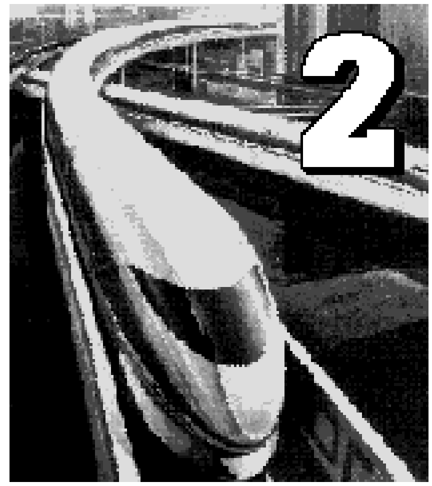
4. What causes the spinning pencil to gradually slow down and stop?

Extention:

Would the number of magnets used affect how the pencil levitates or how long it will spin?



Chapter 2
Magnetism:
A Historical Perspective



Magnetite stones!

The ancient Greeks discovered that certain stones found near the city of Magnesia in Asia Minor had the power to attract bits of iron. Quite appropriately they called these stones magnetite. Legend also tells of a shepherd boy named Magnes, who thrust his iron staff into a hole containing magnetite and found to his dismay that he was unable to remove it. Another story dating back about 2,300 years tells of Ptolemy Philadelphos who had the entire dome of a temple at Alexandria made of magnetite, so that he might be able to suspend a statue in mid-air. The experiment was a failure. Today, it is known that magnetite is an iron ore (a chemical compound of the metal iron and the gas oxygen) which possesses magnetic qualities. It is an unrefined product of nature and is found in nearly all parts of the world. Magnetite is also called loadstone or lodestone. This name came about from its earliest use, its ability to "lead" in a certain direction.

The first legendary account of the use of the magnet for giving directions dates back to 2637 B.C. Hoang-ti, who was said to have founded the Chinese Empire and reigned for 100 years, was pursuing the rebellious prince Tchiyeou and got lost in a dense fog that rolled in from the broad plains. In danger of losing sight of the prince, Hoang-ti constructed a chariot upon which he mounted a female figure that always pointed towards the south, no matter which way the chariot was driven. With the aid of this primitive compass, he was able to follow and capture the rebellious prince.

The fact that a compass needle aligns itself in a particular direction at every point on the earth tells us that the earth is surrounded by a magnetic field. This is as if there were a huge bar magnet running through its center. One pole, called the North magnetic pole, is up near the North geographic pole (actually about 1,400 miles away), and the other pole called the South magnetic pole, is near the geographic South pole (also about 1,400 miles away). The precise distance of the magnetic poles from the geographic poles changes somewhat from time to time.

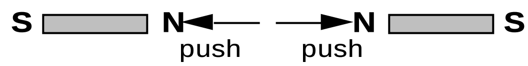
We know now that if the north pole of a magnet is free to turn, it will come to rest pointing towards what has been designated as the North magnetic pole. But we also know that unlike poles attract. Therefore, we know that the North magnetic pole of the earth is actually a magnetic south pole. (Likewise, the earth's south magnetic pole is in actuality a magnetic north pole).

Queen Elizabeth's physician, William Gilbert, did indeed claim around the year 1600 that the earth was a magnet. He proved it by shaping a lodestone in the form of the earth and showed that a compass, when moved around this lodestone, behaved essentially the same way as does a compass when moved on the earth.

Magnets have two ends or poles. One is the "north pole", and the other the "south pole". Magnets are strongest at their ends. The magnet is surrounded by a region of space in which magnetic force can be felt. This region is called a magnetic field. Magnetic fields can be represented by magnetic field lines. Magnetic field lines are imaginary lines that show the direction and strength of the magnetic field. These lines are sometimes called lines of force because the force from north pole to south pole acts along this line. The field that is filled with these lines extends in all directions around the magnet. All the magnetic lines of force added together are called the flux of the magnet.

If you try to push together the north ends of two magnets you will feel a force resisting you. The two north ends push each other away or **repel** each other. The same thing will happen with the two south ends.

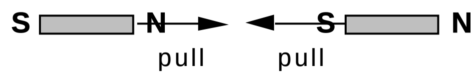
Like poles repel



**Here the two magnets push each other away.
The arrows show which way each magnet will go.**

If you try to push the north end of one magnet toward the south end of another magnet, you will find that you have some help! A north end and a south end pull on each other or **attract** each other.

Opposite poles attract



**Here the two magnets are pulled toward each other.
The arrows show which way each magnet will go.**

Steel contains iron, aluminum doesn't. See what happens when you put a magnet next to different kinds of metal cans. What did you learn from that? What do you think **the door of your refrigerator** is made of?

Any material that is attracted by a magnet is called a magnetic material. Cobalt, nickel, and iron are magnetic metals. Some alloys, or combinations of metals, are also magnetic.

Ordinarily, the atoms in a material point in many different directions. When a magnet is brought near a magnetic material, many of the atoms in the material line up in one direction. When this happens, the material itself becomes a magnet. You can make an iron nail into a magnet, or magnetize it, by bringing the nail near another magnet, by touching it to the end of the other magnet, or by stroking it with the magnet for a few times in the same direction.

If the atoms in a magnetized material fall out of line, the material loses its magnetism. Magnets made of soft iron lose their magnetism in a short time. They are called temporary magnets. Magnets that keep their magnetism for a long time are called permanent magnets. You can destroy the magnetism of a magnet by heating it, hammering it, or stroking it in the opposite direction with another magnet. Any of these actions causes the atoms of the material to fall out of line.

INVESTIGATING THE NATURE OF MAGNETISM

Science Activity 2.1 Every Magnet Has Two Poles

<u>Objective</u>: To show that when a magnet is broken in half it still continues to have both a North seeking pole and a South seeking pole

<u>Materials</u>:
- A compass
- A paper clip
- A magnet
- Wire cutters or clippers

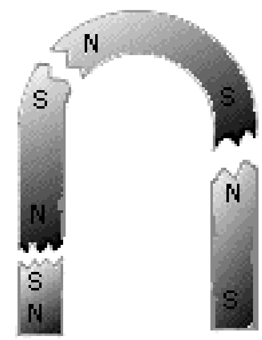


Figure B

Every Magnet Has Two Poles

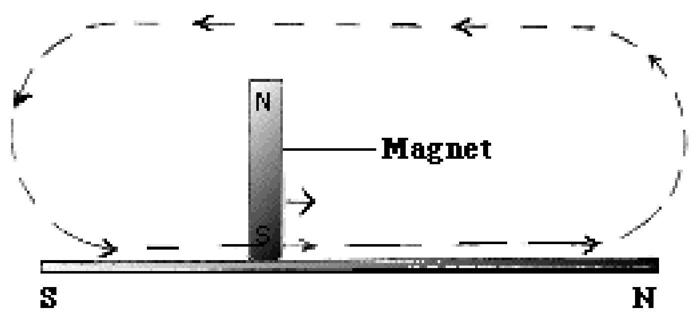


Figure A

<u>Teacher preparation</u>:

If the earth's magnetism is so strong, why can't we use it to do some work? We know that the North pole attracts a North-seeking pole, so why not make a very strong North-seeking pole, attach it to some vehicle, and let the earth's magnetism pull it to the North pole? That sounds good, so let us try to make an independent North-seeking pole.

<u>Procedures</u>:
1. Magnetize a piece of steel wire such as a straight paper clip.
2. Stroke over its entire length with a magnet as illustrated in **Figure A** for about 20 to 30 strokes.
3. Test the polarity of this wire with the compass, and you will see that you have produced a North pole and a South pole.

4. Cut the wire paper clip in half.
5. Test the polarity of the two ends of the wire halves with a compass.
6. Cut one of the halves in half again and test the polarity of each half. **Figure B** illustrates what happens with a magnet or a magnetized paper clip when it is cut.

Assessment and Review:

What happened to the polarity of the small pieces when you cut the paper clip in half?

____
____
____

Extension, reinforcement, or optional activity:

Thus we have found out one of the basic laws of magnetism, which states that every magnet has at least two poles. It is impossible to produce a magnet with only one pole no matter how small we make it.

Science Activity 2.2 Which Pole Is Attracted?

<u>Objective</u>: To demonstrate attractive force of magnets

<u>Materials</u>:
• Two marked bar magnets
• One unmarked bar magnet
• A piece of string

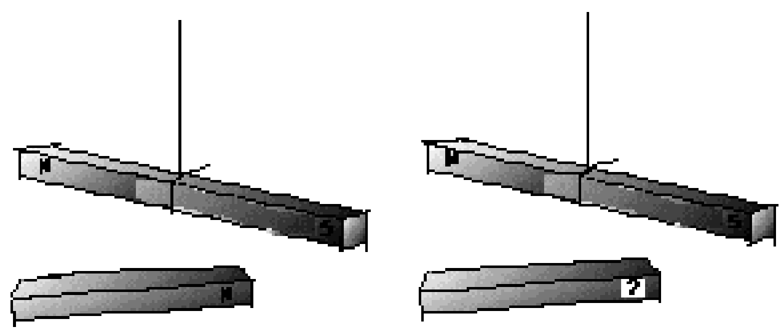


Figure A **Figure B**

Which pole is attracted?

<u>Procedures</u>:
1. Tie a string to a marked bar magnet and let the magnet hang horizontally from the left hand (or from a stand). See **Figure A** above.
2. Approach this free rotating magnet with another marked bar magnet in your right hand. Let students observe what the north and south end of the hanging magnet will do when another north or south end approaches it.
3. Now replace the marked bar magnet in your right hand with an unmarked bar magnet, and ask students: “Which pole will swing towards this approaching magnet?” See **Figure B** above.

4. Wait for students' reactions (some anticipated answers: "We don't know until you tell us what pole is coming near the hanging magnet").

5. Say: "If I tell you what pole I have in my right hand, can you tell me which one will be attracted to it?"

Assessment and Review:

1. Can you make a rule that all magnets will follow?
2. What would the hanging magnet do when approached with a regular steel bar?
3. What can you tell about the approaching bar if the N as well as the S pole swings towards it?

Extension:

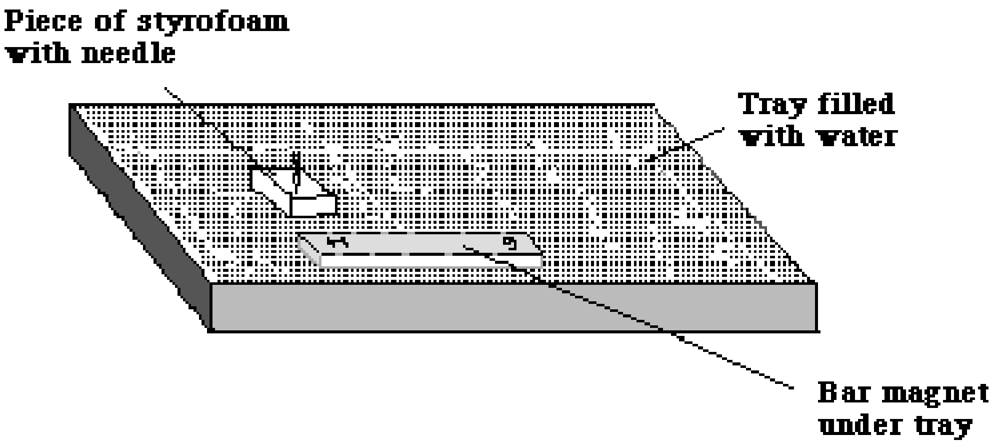
The main purpose of this demonstration is to elicit the rules of magnetism — "Like poles repel and unlike poles attract"— from the students themselves. By showing them the different sketches several times with different poles approaching the hanging magnet, they should be able to form and understand the concept themselves.

By approaching the hanging magnet with an identical steel bar, which is not magnetized, both poles will be swinging towards it. This happens because the molecules in the non- magnetized bar are still randomly arranged and a north as well as a south pole of a magnet can attract the steel bar. A nail will have the same properties.

Science Activity 2.3 The Mysterious Moving Needle

Objective: To show the attractive force of magnets

Materials:
• One strong bar magnet, a medium size sewing needle.
• A wide and shallow glass or plastic tray (to hold water).
• A small cork or small piece of styrofoam.



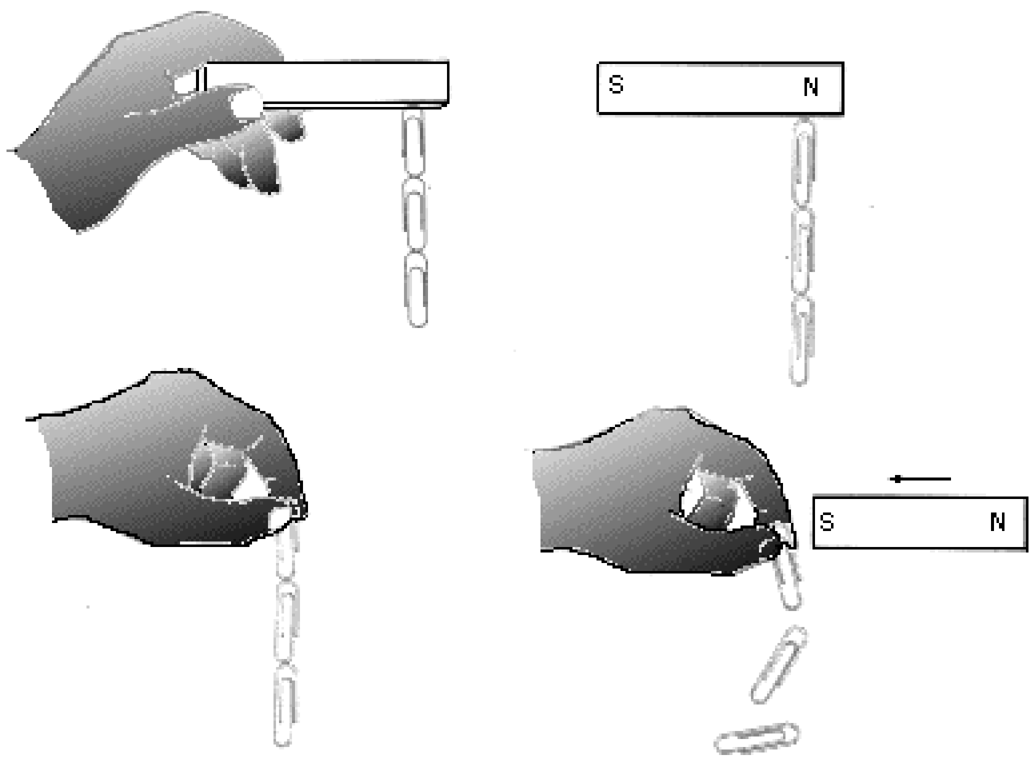
Procedures:
1. Magnetize the needle by rubbing the North pole of the rod magnet several times from the point towards the hole end.
2. Fill the tray with water (about 2 cm deep) and place it on top of the bar magnet (propping the sides so the water level stays horizontal).
3. Pierce the needle through a small cork or a small piece of styrofoam, such that the sharp end points vertically down.
4. Place this needle near the North pole of the magnet and observe! (Make sure that the sharp point just floats 2-3 mm above the bottom of the tray. If it is not, just add some more water to the tray). See diagram above.

Assessment and Review:
1. What did you observe the needle doing?
2. What would it do if the needle is placed near the South pole?
3. Would rubbing the needle with the South pole of the magnet make any difference in move ment?
4. What difference would it make if the needle was rubbed with the North pole but in the opposite direction (from hole to sharp end)?
5. Why doesn't the needle move in a straight line towards the poles?

Science Activity 2.4 Induced and Residual Magnetism

Objective: To show how materials closest to a magnet will acquire induced and residual magnetism.

Materials:
- Number of paper clips
- Magnet
- Nail and filings



Procedure:
1. Hold a paper clip against one of the poles of a magnet. Touch the other end of this clip with another clip, that second clip, will be held fast to the first by magnetic attraction. The magnet induces magnetism in the clip which is held to it. This clip in turn induces magnetism in the second clip, so that it too becomes a magnet and thus is able to attract the third clip.
2. Remove the magnet from the clips. The clips will probably separate. The clips may separate or not depending on the *retentivity* of the material of which the clip is made.

Retentivity is a term which indicates how long a substance will retain its magnetism after the magnetizing force is removed. Note: If two clips still stick together, this indicates that the magnetism in at least one of them did not completely disappear and that the molecules main tained their alignment after the inducing magnet was removed. *Residual magnetism* occurs when magnetism is a result of the retentivity of the material!

3. Approach the end of the clip very slowly from which the magnet was removed with the other pole of the magnet. You will see than even before the magnet touches the clips, they will separate. This is because you are now inducing magnetism of the opposite polarity, and the other end of the clip will now have a polarity which is the same as that of the clip which it is holding up. As like poles repel, so the clips will separate.
4. Dip one end of soft iron bar or nail into some iron filings. The filings will not stick to the nail when you pull it out.
5. Bring a permanent magnet near the top of the iron nail while it is submerged in the iron filings. Then lift the magnet and the nail, and you will see that some of the filings will stick to the nail.
6. Move away the magnet and the iron filings will lose most of their magnetism and will drop off. Some of the filings that stick to the nail will do so because of residual magnetism of the nail.
7. Turn the magnet over, and the filings will fall off the nail for the same reasons explained previously.

Assessment and Review:

1. What did you observe when the magnet was removed from the paper clips that were sticking to each other?
2. How do you define residual magnetism?
3. What do we mean by the retentivity of the material?
4. After the magnet was removed, why did some filings stick to the nail?
5. Give one example of induced magnetism.

Extension:

Experiment with other metal objects like pins and needles to find out how much residual magnetism each item can attain. Determine the number of pins or needles that can be held by one pin with residual magnetism.

Science Activity 2.5 Making Magnets

Objective: To identify different kinds of materials that can be used to make magnets.

Materials:
- Alnico (or other strong) magnet
- Sewing needle, steel knitting needle, or iron nail
- Dozen paper clips

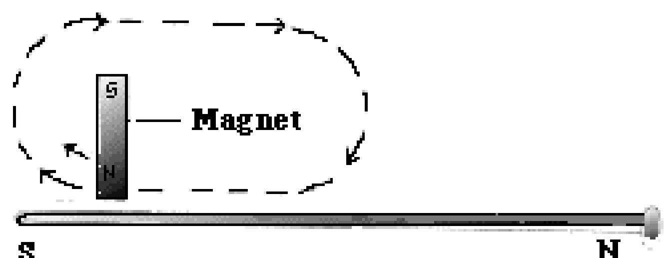


Figure A

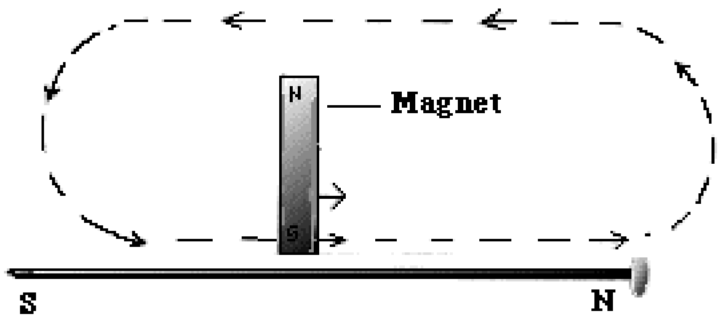


Figure B

Teacher Preparation:

Soft iron can be quickly magnetized, but it will lose its magnetism rather easily. Hardened steel or certain steel alloys, on the other hand, though more difficult to magnetize, will retain their magnetism for a much longer time.

Procedure:

To magnetize the whole needle at once, hold it at one end and rub it with one pole of the magnet about ten times as shown in **Figure A**. This is not a back-and-forth motion but a unidirectional motion. Remove the magnet from the needle each time as soon as you reach the far end.

To magnetize the needle by halves, hold the magnet in one hand and the needle in the other. Stroke the needle from the middle to one end with one pole of the permanent magnet. To do this, carefully place the center of the needle against the pole of the magnet, hold the needle there, and pull the magnet out (**Figure B**). Repeat this about 10 time. Then hold that end of the needle which has now been stroked, and repeat the procedure with other end of the needle. This time, stroke it an equal number of times with the other pole of the magnet. The needle is now magnetized, as you can prove by touching it to a number of paper clips. Of course, they will be attracted to either end of the needle, where we now have produced a North pole and a South pole.

This process of magnetization can be used on any substance which initially is attracted by the magnet. In other words, any material which is magnetic can be magnetized.

Assessment and Review:

Though we did not change the outward appearance of the needle, what happened to it to make it behave like a magnet? Materials such as iron and steel are made up of very small particles that act individually like small magnets. Each of them has a North and a South pole, but before the material is magnetized, these poles all point in different directions.

By stroking with the magnet, we essentially line up these elementary magnets and make them all point in the same direction. That is, all the North poles face in one direction, and all the South poles in the other, whereas previously there was no order in their arrangement. This alignment of elementary magnets is readily accomplished in some materials and is more difficult in others. In some, this alignment lasts for a long time, and in others it does not. It all depends on the nature of the material we are dealing with.

If you wish to locate the North and South poles in a particular direction, remember that the end of the needle which last touched the South pole becomes a North pole, and that end which is rubbed against the North pole becomes a South pole. You can test this polarity with a compass.

Science Activity 2.6 Making Magnets Stronger

Objective: To compare the strength of magnets

Materials:
• A strong magnet
• Two iron nails, paper clips
• Two screw drivers (large & small)

Teacher Preparation:

Most manufactured magnets are made from steel. Named for their shapes, they are bar, V, U, horseshoe and cylindrical magnets. Since some magnets tend to be stronger than others, try to have several kinds of magnets on hand for this activity.

The magnets made in this activity tend to be weak, so only light objects will be noticeably attracted. If the paper clips are too heavy, try steel straight pins.

Iron and steel may be magnetized by a magnet. It takes longer to magnetize steel than it does to magnetize soft iron. Soft iron objects are easier to magnetize but attraction weakens after a few minutes.

Procedures:
1. Stroke a large nail with a strong magnet 10 times. Each stroke on the nail should be in the same direction and with the same pole of the magnet. Why?
2. Now, dip the nail into a box of paper clips and slowly lift the nail. How many paper clips were attracted to the nail?
3. Stroke the nail the same way 10 more times and repeat the test. How many paper clips were attracted?
4. Continue this process, by 10 stroke amounts, until the magnet picks up no additional paper clips. Record all data on the chart below. Then transfer that data to a graph.

Assessment and Review:
1. Using the data from the chart and graph above, describe how the number of strokes changes the strength of the magnetism of the nail.
2. When did the nail no longer pick up more paper clips? Why?
3. Suppose you were to stroke another nail back and forth, instead of one way. How strong will the magnet be after 20 strokes? 30 strokes? 40 strokes?

Extension:

Use other steel objects to learn more about magnetizing. Notice that if an object is attracted to a magnet, then it can be made into a magnet. Magnetism can be induced in both soft and hard steel. A steel object, such as a screwdriver, retains its magnetism. However, steel is harder to magnetize. Remember that stroking an object both ways with a magnet is less effective than stroking it in one direction.

EXPLORING MAGNETIC FIELDS

Science Activity 2.7 Homemade Compass

Objective: To show the direction of earth's magnetic field

Materials:
- Wide-mouth glass jar
- 3x5 index card
- Scissors and tape
- . Long sewing needle
- Thread
- Bar magnet
- Pencil

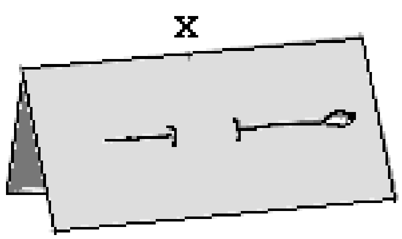


Figure 1

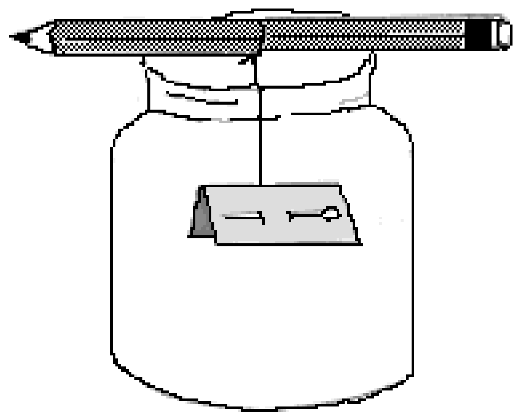


Figure 2

Procedures:
1. Cut a strip 5 cm wide from the short side of the index card. Fold the strip in half lengthwise.
2. Magnetize the needle by stroking it 12 times in one direction with the bar magnet.
3. Put the magnetized needle through the folded strip as shown in **Figure 1.**
4. Cut a piece of thread long enough to reach from the top to just below the middle of the jar. Tape the thread to the center of the card, shown as point X on **Figure 1**.
5. Slide the needle to the left or right in order to make the card hang level when supported by the string.
6. Tie the end of the string around the pencil, and hang the card inside the jar as shown in **Figure 2**.
7. Turn the jar slowly, first in one direction and then in the other.
   Observe the movement of the needle.

Assessment and Review:

I.

1. When you turned the jar, what happened to the card with the needle in it?
2. Explain your observations.

II.

Word Activity

Match the scrambled word on the left to the definition on the the right:

1. nagmecit lefid	a. Space in which magnetic force is felt
2. nisel of cofer	b. Place toward which a compass needle points
3. samsopc	c. A magnetic needle that can move freely
4. gaicmnte lope	d. Lines that show the direction of a magnetic field

III.

Fill in each blank with the word or words that will make the sentence true. Use the words below.

poles magnetized geographic south

1. The magnetic field of the earth is strongest at the________________.
2. The North Magnetic Pole is near the North ____________________________pole.
3. A compass is a freely-moving needle that has been_____________.
4. If you move a bar magnet close to a compass, the north pole of the compass needle will point toward the magnet's____________________ pole.

IV.

Decide if each statement is true or false. In the space provided write T or F. If the statement is false, correct the underlined word or words.

__________1. <u>Lines of force</u> show the direction of a magnetic field.

__________2. The earth is surrounded by a <u>magnetic field.</u>

__________3. The region surrounding the earth in which the earth's magnetic force is noticeable is a <u>magnetic pole</u>.

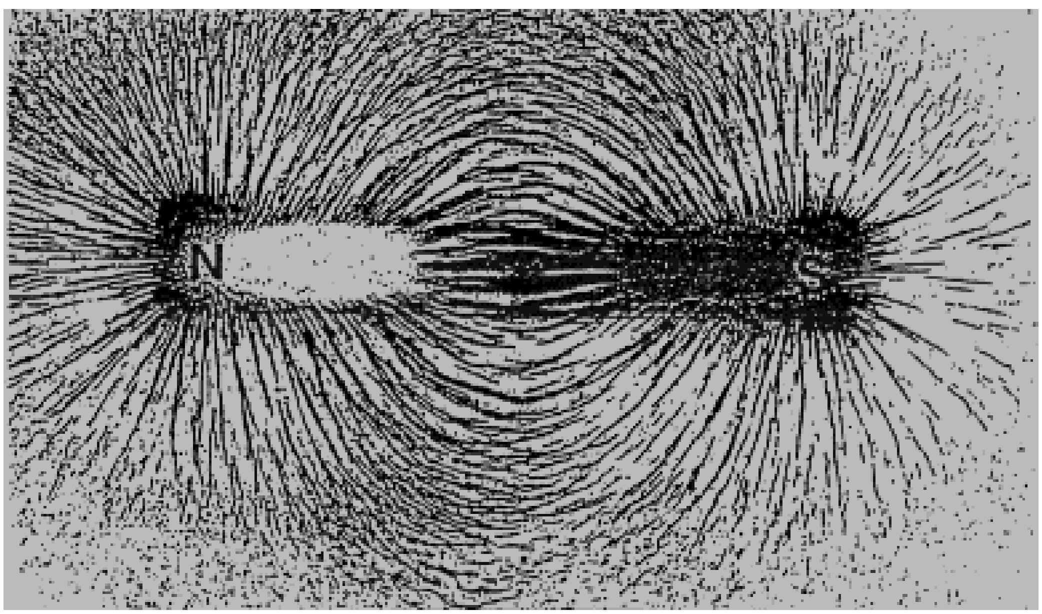
__________4. The earth's lines of force are strongest around the <u>equator</u>.

__________5. A compass is a <u>magnet</u>.

Science Activity 2.8 Magnetic Fields Around Magnets

Objectives: 1.To observe characteristics of isolated fields.
2. To observe interaction of magnetic fields.

Materials:
- Piece of soft iron
- Two bar magnets
- Iron nail
- Small iron washer
- Small magnetic compass
- String
- Iron filings
- Thin sheet of cardboard or glass
- Paper clips (steel)



The magnetic field around a bar magnet

Teacher Preparation:
Although many substances exhibit slight magnetic properties, only iron, cobalt,nickel, and their alloys make strong permanent magnets. Magnets made of these substances or of

alloys containing these metals are capable of attracting or repelling other magnets through a distance with no apparent connection between the interacting magnets. If an object contains iron, cobalt, or nickel and a magnet is brought close to it, the magnet will cause, or induce, magnetism in the object and will then interact with it. Thus, a magnet can attract a nail that is not at first a magnet.

Whenever one body exerts a force on another through a distance, the concept of a field of force is used to describe the interaction. We use the idea of a gravitational field to explain how a body is pulled toward the earth. We use the idea of the electric field to describe the way in which electrically charged bodies attract and repel one another.

Effects of magnetic fields, unlike those of gravitational or electrical fields, are rather easy to observe. If a magnet is suspended, so that it is free to rotate in a horizontal plane, the magnet will come to rest in a roughly north-south position. The end of the magnet that points toward the north is called the north-seeking or north (N) pole of the magnet. The opposite end of the magnet is called the south-seeking or south (S) pole of the magnet. A compass is a small magnet, free to pivot in a horizontal plane.

Procedures:

A. Polarity Check

Using the string, suspend the magnets one at a time. Be careful that you do not suspend them near an iron or steel object. The pole marked N on the magnet should point north when the magnet comes to rest.

B. The Magnetic Field

1. Place a bar magnet on the table and cover it with the piece of cardboard. Gently and evenly sift iron filings on top of the cardboard. Tap the cardboard lightly with your finger until the filings form a definite pattern.
2. Draw the observed pattern on Figure 2.
3. Notice that the filings seem to follow definite lines from one end of the magnet to the other. These are called magnetic field lines. Notice also the field lines never overlap. Return the iron filings to the container.

C. The Magnetic Field Between Like Poles

1. Place both magnets on the table with the N pole of one magnet about 4 cm from the N pole of the other (See Figure 3)
2. Cover the two bar magnets with the cardboard and sprinkle filings onto the card board. Tap the cardboard lightly.
3. Draw the resulting pattern on Figure 3.

D. The Magnetic Field Between Unlike Poles

Place unlike poles facing one another in the same way that you did with the like poles in Part C. Repeat the procedure and draw the pattern on Figure 4.

E. Induced Magnetism I

1. Arrange the piece of soft iron between unlike poles of the bar magnets. Leave about 1.5 cm between each magnet and the piece of iron.
2. Repeat the procedure outlined in Part C and draw the pattern on Figure 5.

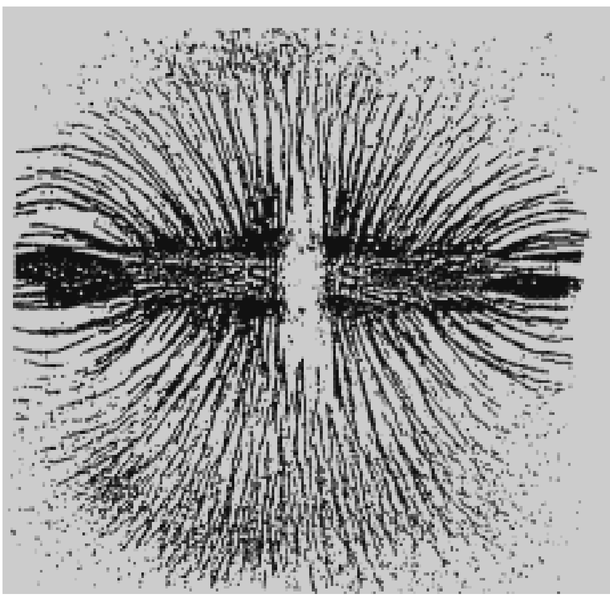
F. Induced Magnetism II

1. Test an iron nail for magnetism by touching it to some paper clips. Touch the nail with one end of a magnet. Test the nail again while it is attached to the magnet. Record your observations.

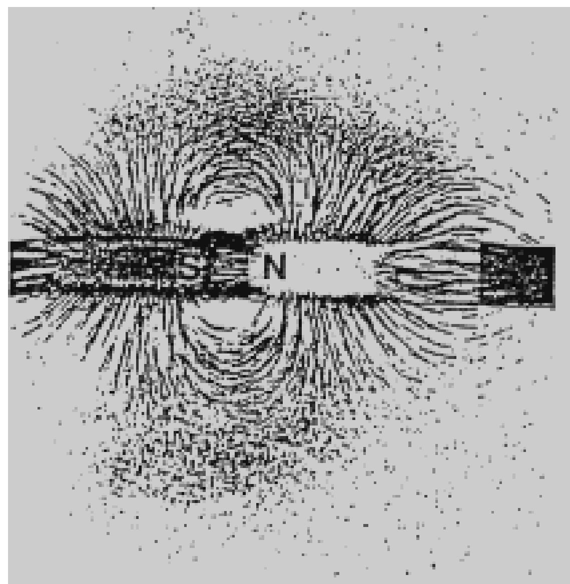
2. Suspend the second magnet with a piece of string. With the iron nail at one end of the first magnet, test the free end of the nail for polarity. Compare the polarity of the free end of the nail with the polarity of the end of the magnet to which it is attached. Are they the same or opposite?

G. The Direction of a Magnetic Field

1. Place the compass at one corner of the N pole and note the direction in which the north seeking pole of the compass points.
2. Slowly move the compass in a flattened arc from the N pole to the S pole of the magnet. Record your observations.
3. Place the compass between the N pole of one bar magnet and the S pole of the other. Record your observations.



The magnetic field between like poles



The magnetic field between unlike poles

<u>Assessment and Review</u>:

A. Polarity Check

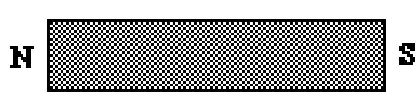
Observations

____

____

B. The Magnetic Field

Figure 2



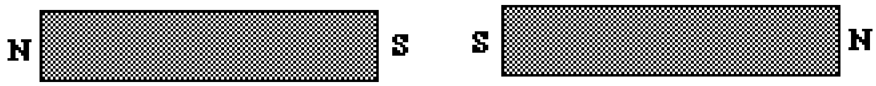
Observations

____

____

C. The Magnetic Field Between Like Poles

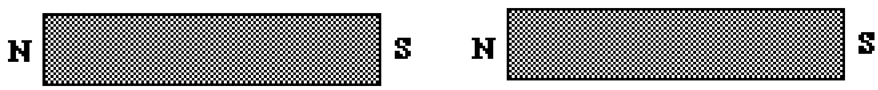
Figure 3



Observations

D. The Magnetic Field Between Unlike Poles

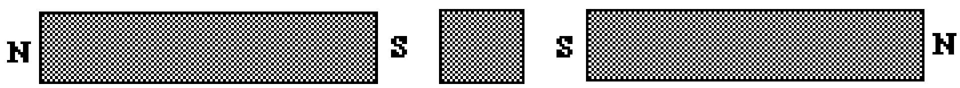
Figure 4



Observations

E. Induced Magnetism I

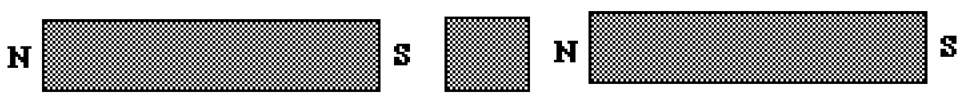
Figure 5



Observations

F. Induced Magnetism II

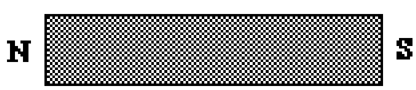
Figure 6



Observations

G. The Direction of a Magnetic Field

Figure 7



Observations

Reinforcement:

1. Near what points is the magnetic field around a magnet strongest?
2. Describe the magnetic field lines between two like poles.
3. Describe the magnetic field lines between two unlike poles.
4. When a nail is attached to a magnet, how does the polarity of the free end of the nail compare with the polarity of the free end of the magnet?

Extensions:

1. Study the topic of magnetic shielding. Discuss some important applications, such as color television tubes.
2. Place an iron washer between unlike poles of two bar magnets. Cover the magnets and washer with a piece of cardboard and sprinkle filings onto the cardboard. Tap the card board until a definite pattern appears. Draw the pattern. Describe the field produced.

Science Activity 2.9 Investigating Magnetic Lines Of Force

Objective: To determine magnetic lines of force

Materials:
• Two bar magnets
• Small compass
• Several sheets of white paper 40 x 50 cm
• Transparent tape

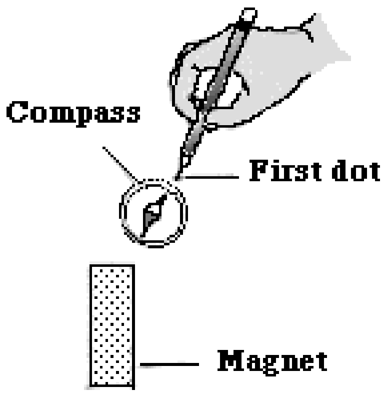


Figure 1

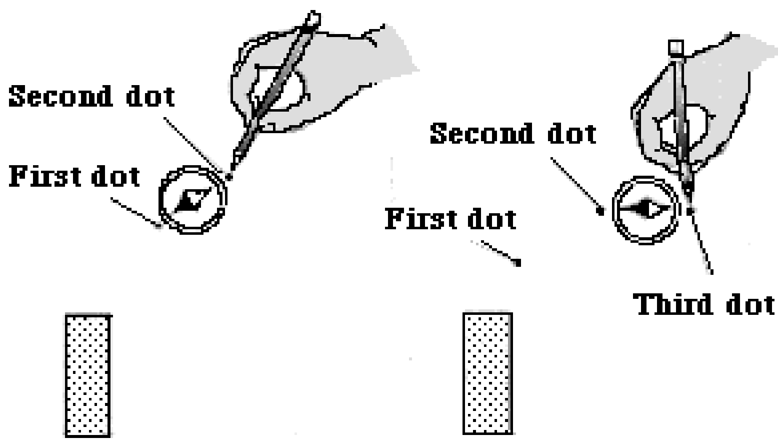


Figure 2

Teacher Preparation:

A magnetic field surrounds any magnet. This field is made up of lines of force that are arranged in a definite pattern. Where the lines of force are closest together, the magnetic force is the strongest. It is possible to trace the pattern of the magnetic lines of force by using a small compass. The compass needle will align itself along the magnetic lines of force.

In this investigation, one will trace the pattern of the magnetic lines of force of a bar magnet. One will also explore the pattern of combinations of bar magnets.

Procedures:
1. Place one bar magnet in the center of a large sheet of white paper. Tape the magnet in place so that it will not shift position.
2. Place the compass beside one pole of the magnet. Make a pencil dot on the paper at the outward end of the compass needle (the end pointing away from the magnet). Move the compass farther out, crossing over the dot. Move it until the opposite end of the needle is

at the dot, as shown in **Figure 1** on page 31. Place another mark at the outward end. Continue to move the compass until it goes off the paper or returns to the magnet. Let the turning of the needle to new positions direct your placement of dots. Connect the dots with a smooth line. See **Figure 2** on page 31.
3. Repeat this process but start at another point at the end of the magnet. Draw at least five lines of force.
4. Sketch the results in Drawing 1 on page 33.
5. On a new sheet of paper, align two bar magnets so that they are parallel with like poles pointing in the same direction. The magnets should be about 7 cm apart.
6. Repeat the procedure with the compass and trace the lines of force. Sketch the results in Drawing 2 on page 33.
7. On another sheet of paper, align two bar magnets parallel with unlike poles pointing in the same direction. The magnets should be about 7 cm apart.
8. Repeat the procedure with the compass and trace the lines of force. Sketch the results in Drawing 3 on page 33.

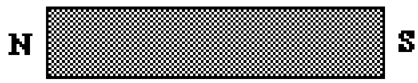
Assessment and Review:

1. What general description of lines of force can you conclude from the drawings?
2. What happens to the lines of force if like poles of two different magnets are placed close together?
3. What happens to the lines of force if unlike poles of two different magnets are placed close together?
4. Where are lines of force closest together? What does this mean about the strength of the magnetic field at these points?

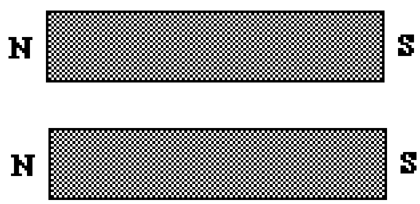
Extension:
1. If you held a bar magnet in each hand with unlike poles facing each other, what would you feel as you brought the magnets near each other? What would you feel if you brought like poles near each other?
2. What would happen to the lines of force if like poles of two different magnets are placed close together?
3. Suppose two bar magnets were suspended in air side by side. How would they align themselves?
4. Use a drawing to predict what the lines of force would look like if two bar magnets were placed end-to-end with **unlike** poles facing each other or with **like** poles facing each other.

Optional Activity:
1. Move the compass above the plane of the paper and below the plane of the paper. Do magnetic lines of force exist in three dimensions?
2. Sketch the lines of force of a horseshoe magnet. What does this mean about the strength of a horseshoe magnet?
3. Do the lines of force of an electromagnet disappear when the electricity is shut off? Devise an experiment to determine the answer.

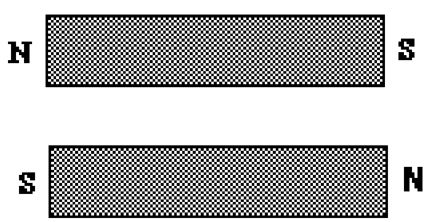
Drawing 1:



Drawing 2:



Drawing 3:



Science Activity 2.10 How Can We See Magnetic Fields?

Objectives: To create a permanent print of magnetic fields

Materials:
- White typing paper
- Iron filings
- Bar magnet
- Spray bottle containing water
- Clear acrylic fixative

Procedures:
1. Place the bar magnet on the table, cover with typing paper, sprinkle on the iron filings.
2. Spray water on the iron filings and allow them to rust on the paper over the magnet; permanent “rust images” can be created.
3. Spray with clear acrylic spray.

Assessment and Review:

To evaluate student understanding, a teacher could prepare a similar sheet of white paper without placing over a magnet and ask students to describe and explain the difference between the randomness of the one prepared without the presence of a magnetic field, and the one created in a magnetic field.

Activity 2.11 A 3-D Model Of A Magnetic Field

<u>Objective</u>: To create a 3-D model of a magnetic field

<u>Materials</u>:
- One quart clear glass jar
- Large package of clear gelatin (lemon)
- Cooking utensils
- Bar magnet
- Iron filings

<u>Procedures</u>:
1. Suspend the bar magnet from the string in the jelly. Just before jelly sets, gently sprinkle in about a teaspoon of filings. Tap jar to eliminate bubbles. Put the jar in the refrigerator for about an hour.
2. Draw the three-dimensional view of the magnetic field.

<u>Assessment and Review</u>:

In an appropriate container, the solid gelatin mass can be cut along different planes to see the different spacial relationships of the field.

Science Activity 2.12 Lines Of Force Photography

Objective: To understand magnetic lines of force caused by a magnetic field by creating a photograph of them.

Materials:
• Photographic contact printing paper
• Stop bath
• Fixing bath (hypo)
• Magnet
• Iron filings
• Lamp with 100 watt bulb
• Source of water running

Procedures:
1. Set the magnet on the paper and prepare the fields. (This can be done in dim light; darkness not essential).
2. Expose the set up to the 100-watt light bulb for 10 seconds.
3. Remove the magnet and place paper in developer.
4. When clear image appears, transfer to stop bath, then into stop bath for 30 seconds.
5. Wash in running water for one hour.
6. Describe what happens and why you think it happens

____

____

Assessment and Review:
Use solar print paper, available at toy stores and museums. It can be substituted for the photographic contact printing paper. Follow the manufacturers instructions on how to use it.

Activity 2.13 Lines Of Force In Wax Paper

Objective: To create a permanent picture of magnetic lines of force

Materials:
• Wax paper
• Index cards (5x8)
• Iron filings
• Masking tape
• Bar magnet
• Electric iron

Procedures:
1. Tape the wax paper to the card. Place the magnet under the card and sprinkle iron filings on the wax paper.
2. Place a warm iron 5 cm above the wax paper with the pattern that shows the magnetic field.
3. Move the iron constantly in a circular path to avoid burning waxed paper (or cover with paper before ironing).
4. Describe and explain what happens.

Assessment and Review:
Half gallon milk container can be substituted for wax paper. Iron filings will become imbedded.

Activity 2.14 Relating Magnetism To Electricity

Objective: To demonstrate that there is a magnetic field around any wire carrying a current

Materials:
- Insulated copper wire (25-30 gauge) cut into 30 cm and 10 cm lengths
- Iron filings
- Bits of paper
- Two 6-volt lantern batteries

Teacher Preparation:

Pre-cut several sets of wire to enable students to work in groups of 2-3. Use wire strippers to strip the ends of the wires and the centers of the longer wire. (Do not use wet cells because of explosion danger.) Distribute iron filings in small containers. Bits of paper should be confetti sized. Try this experiment before using it with students. If it does not work well, try making a loop out of the exposed section of the copper wire which is used to pick up the iron filings.

Procedures:
1. Sprinkle some iron filings on a sheet of paper.
2. Use the 10 cm length of wire in connecting the positive terminal of the battery to the negative terminal of the other battery. Use the 30 cm length of wire to connect the other terminals of the batteries.
3. Holding the insulated part of the 30 cm wire, place the exposed copper center of the wire on the iron filings. Make sure the copper wire touches the filings. Slowly lift the wire.

Assessment and Review:

1. Observe and record what happens.

____

____

2. Predict what will happen if one end of the wire is disconnected.

____

____

3. Disconnect the wire and note what happens.

____

____

4. Experiment with small bits of paper substituted for the iron filings.

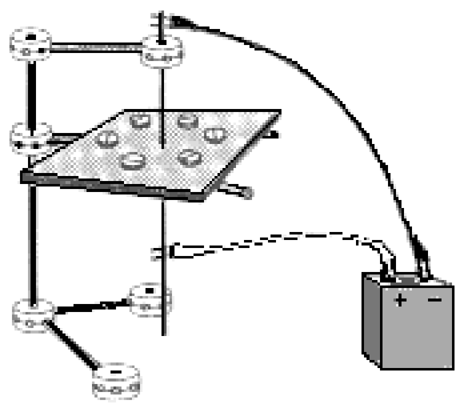
5. Compare the results of the experiment with the iron filings with the bits of paper.

6. What can you now infer about the relationship between electricity and magnetism?

Science Activity 2.15 Circles Of Magnetism

Objective: To show the shape of magnetic fields as a set of concentric circles surrounding a magnet.

Materials:
• One 6 or 12-volt lantern battery
• One inch length of heavy wire (such as a coat hanger)
• Tinkertoy set or ring stand
• A flat, rigid support surface measuring approximately 6"x 6" (or cardboard)
• Four to six compasses
• Two electrical lead wires with alligator clips at both ends



Teacher Preparation:
Compass needles are little magnets that are free to rotate. Compasses allow us to observe the direction of a magnetic field. They normally respond to the earth's magnetic field, orienting themselves parallel to magnetic field lines. If we create a magnetic field which is stronger than the field of the earth (by using electric current) a compass needle will orient itself parallel to the new field.

The electric current passing through the wire creates a magnetic field that is stronger than the earth's field. You can visualize the shape of this new field as a set of concentric circles surrounding the wire. Each of these circles has its center at the wire.

The closer to the wire you are, the stronger the magnetic field. The compass needles align themselves with the total magnetic field at each point, the sum of the earth's field and that of the wire. Since the magnetic field from the wire is larger than that from the earth, each needle ends up pointing essentially in the direction of the magnetic field of the wire.

When you reverse the current, the direction of the magnetic field also reverses, and the needle follows it.

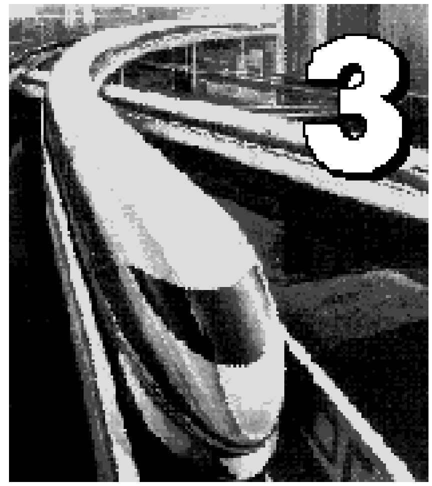
Procedures:

1. Construct a stand and lay the flat support surface in position on the stand (See diagram)
2. If the coat hanger wire is pointed, scrape the coating off to expose about 2.5 cm of bare metal at each end.
3. Insert the wire through the hole in the flat support surface and support the wire vertically in the stand.
4. Arrange the compasses in a circle on the support surface.
5. Attach one alligator clip lead wire to each battery terminal, but do not attach the other end of the lead wires to the coat hanger wire at this time.
6. Observe the compass needles around the wire when there is no current passing through the wire. Rotate the support surface. What happens to the compass needles? (They will all point north.)
7. Attach the alligator clips to the ends of the coat hanger wire where it has been scraped. Watch what happens to the compass needles as current passes through the wire. Each compass will point in a direction tangent to a circle centered on the wire.
8. Rotate the support surface again. What happens to the compass needles this time? The compasses continue to point in a direction tangent to a circle centered on the wire. (Do not leave the wires connected to preserve the battery.)
9. Switch the alligator clips to the other terminals of the battery. What happens? (The com pass needles will reverse direction when the electrical current reverses direction.)

Assessment and Review:

1. Draw a diagram of procedure #6.
2. Draw a diagram of procedure #7.
3. Draw a diagram of procedure #8.
4. Draw a diagram of procedure #9.

Chapter 3
Electromagnetism



Electromagnets

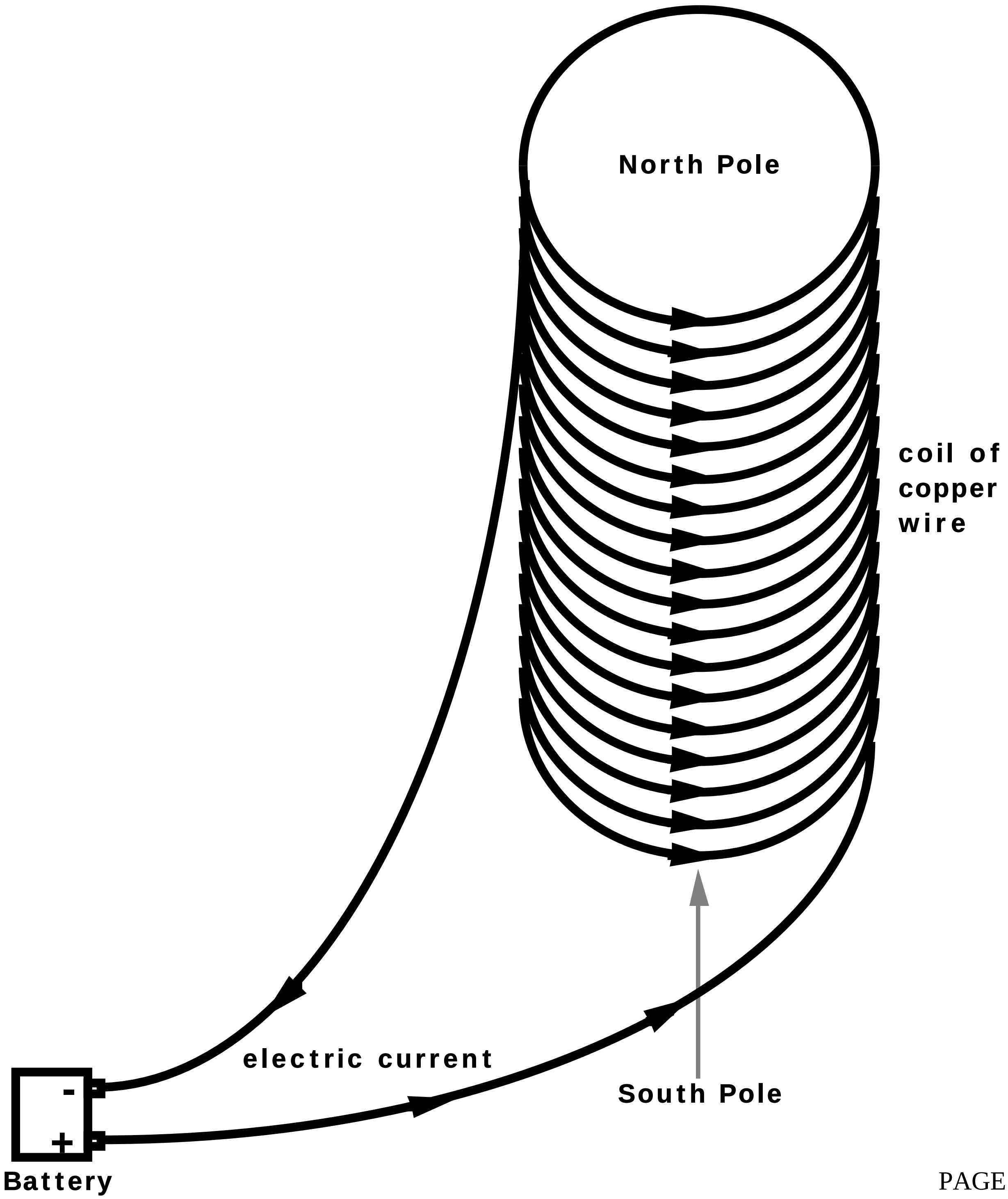
What They are and How to Make One!

About 1820, twenty years after Volta invented the battery, Hans Christian Oersted (1777-1851), a native of Denmark and a professor of physics at the University of Copenhagen, made the discovery that there is a direct relationship between magnetic force and electric force. This began the new science of electromagnetism.

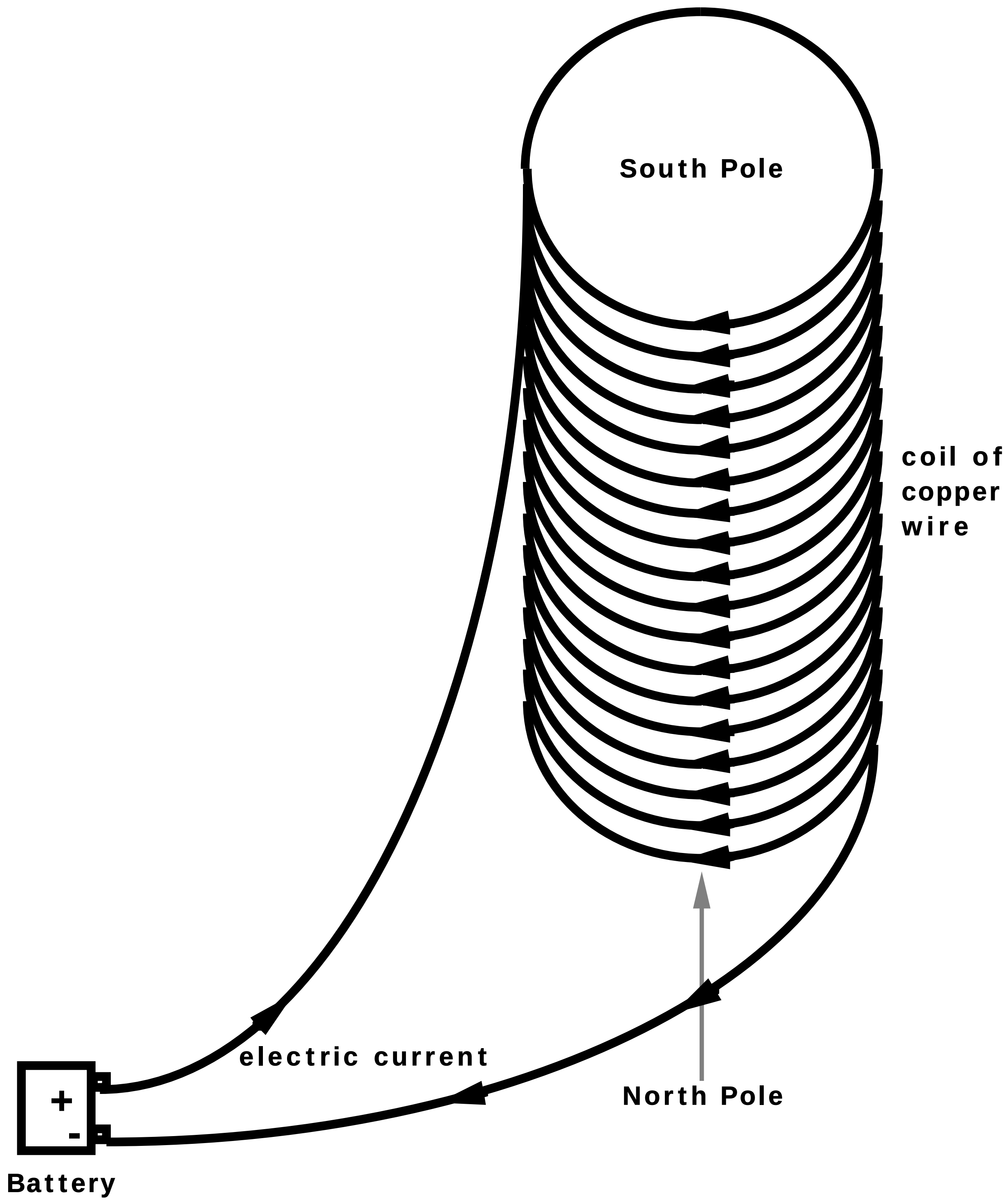
Electromagnets are magnets which are created by electricity. In its simplest form, an electromagnet is a coil of wire both ends of which are attached to opposite ends of a battery. The battery causes an electrical current to flow through the wire. According to the laws of physics, **when an electric current flows through a coil of wire, magnetic poles will be created at the ends of the coil.** The pictures below illustrate this situation. Note that when the direction of the current is reversed, the magnetic poles are also reversed!

Electromagnetism is a simple technique that is commonly used to make electromagnets stronger. If iron is put in the center of the electromagnet (we then call it an iron-cored electromagnet) the magnetic forces from that electromagnet will be greatly increased. **This is something that you can test yourself!** The addition of the iron core, which becomes magnetized by induction, can multiply the strength of the magnetic field by a factor of 100 to 1000. The first electromagnet was invented by William Sturgeon in England in 1824. It could lift 4.5 kg. Modern electromagnets used in industry for lifting scrap metal can lift over 25,000 kg of ore.

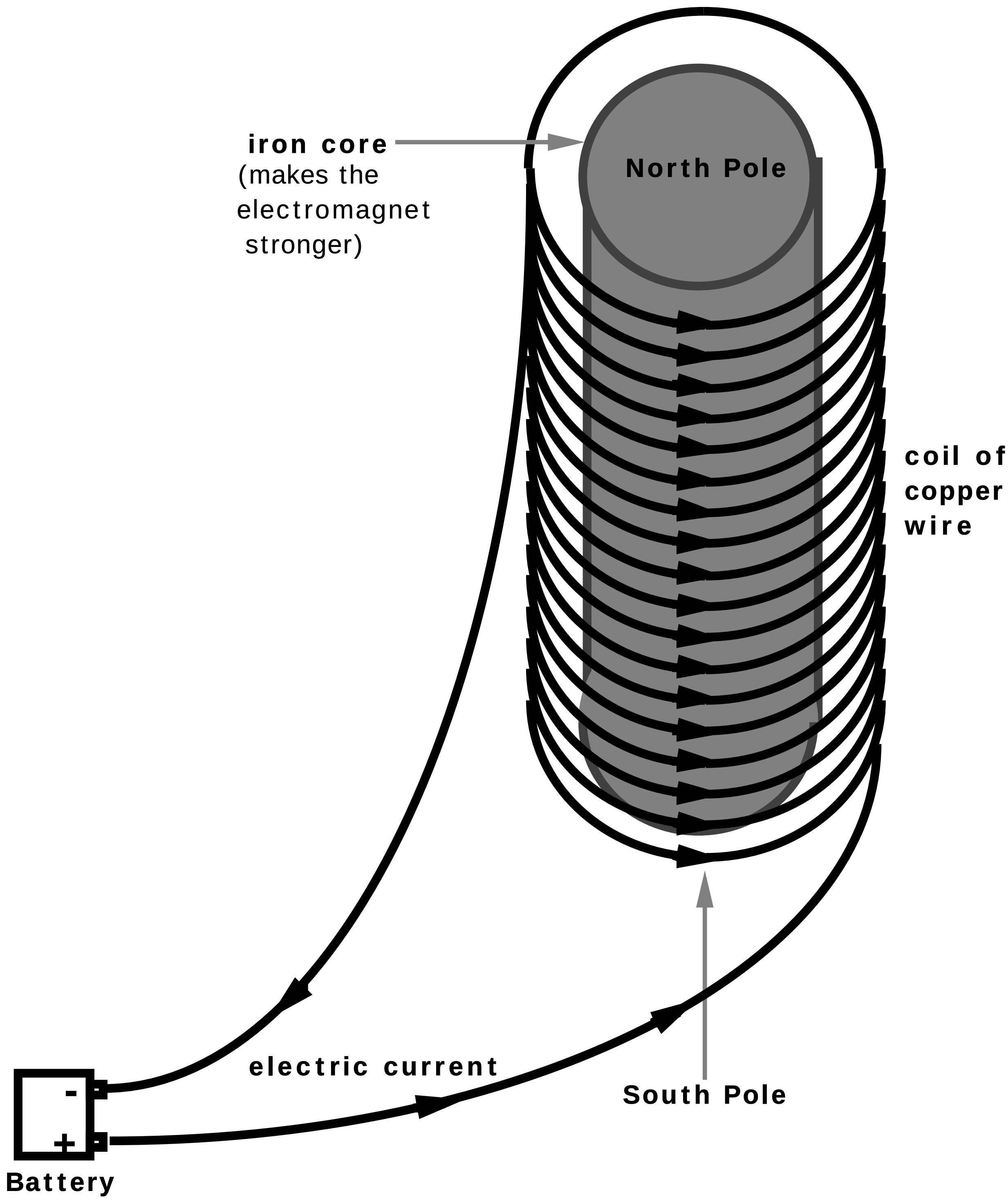
Electromagnet



Electromagnet



Iron-cored Electromagnet



DISCOVERING THE NATURE OF ELECTROMAGNETISM

Science Activity 3.1 Iron-Cored Electromagnetism

Objective: To make an iron-cored electromagnet and compare its strength to a regular magnet.

Materials:
• Insulated electrical wire
• Electric battery (6 or 12 volt will do)
• A few steel nails
• Wooden or plastic rod or a straw (a cardboard tube will also do)
• Bar magnet (optional)

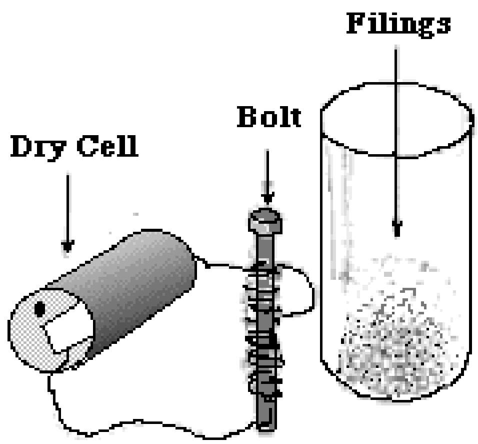
Procedure:
1. Students can make an iron-cored electromagnet by simply wrapping some wire around an iron or steel nail and connecting the two ends of the wire to a battery.
2. With the electromagnet "on" (when it is connected to the battery) take another nail and bring it close to the end of the electromagnet.
3. Students should feel magnetic attraction — the nail in their hands will be attracted to the electromagnet.
4. Ask what will happen if you bring a bar magnet close to the end of the electromagnet? One end will be repelled and the other attracted to it!
5. To compare the strength of the iron-cored electromagnet with the strength of a regular electromagnet, wrap wire around a wooden or plastic rod or even a cardboard tube or a straw, and connect the ends to a battery. 6. The tube should be the same size as the nail, and the wire should have the same number of turns as the nail.
7. Bring a nail close to the end of the new electromagnet and notice that it isn't pulled as strongly as it was by the iron-cored electromagnet.

Assessment and Review:
1. Why does iron in the middle make an electromagnet stronger?
2. What makes an electromagnet strong?

Science Activity 3.2 Constructing Electromagnets

Objective: To make a simple electromagnet

Materials:
• A nail at least 6cm long
• Three meters of insulated copper wire
• Six-volt battery
• Some paper clips, tacks, pins, or other small magnetic objects.



Teacher Preparation:

One of the greatest practical benefits of Oerstead's experimentation was the discovery of the electromagnet. It was conceived independently by Joseph Henry, an American Scientist, who was the head of the Smithsonian Institute, and William Sturgeon, an English physicist. Many scientists today consider it as one of the greatest inventions of modern times.

In 1825 Sturgeon bent an ordinary iron bar into a horseshoe. He then coated it with varnish and wrapped it with bare copper wire. When he ran current from a voltaic battery through the wire, the horseshoe became a magnet which was capable of supporting a weight of over 13 kilograms.. Stronger and stronger electromagnets were soon developed based on this principle.

Electromagnets are temporary magnets that can be turned on and off readily. If necessary, they can be made very strong. They are found in doorbells, door chimes, telephone receivers, telegraph sets, relays, loudspeakers, electric clocks, fans, refrigerators, washing machines, mixers, generators, circuit breakers, automatic switches. Cranes with lifting magnets are used for loading and unloading iron and for separating iron and steel from other metals.

Procedures:

1. It is quite simple to make an electromagnet. Beginning about 30 cm or so from the end of the wire, wind it around the nail, starting at either end. Keep winding layer after layer, always in the same direction, until about 30 cm of wire is left. At this point it is advisable to wrap some tape around the winding to hold it in place. Scrape the insulation from both ends of the wire, and connect one end to one of the terminals of the battery.
2. Hold the electromagnet over a small pile of tacks or pins and top of the other end of the wire onto the other battery terminal. At that very instant, the tacks will jump up to either one or both ends of the nail, which now acts like a magnet. Take the wire off the battery terminal, and the tacks will immediately fall off. Perhaps one may still stay on. Here is what is happening:
3. We showed earlier that current through a wire produces an invisible magnetic field. When the wire is wrapped around a piece of soft iron, the magnetic field magnetizes the iron by changing the position of its molecules and lining them all up in the same direction. How ever, when the current is turned off and the magnetic field disappears, then the molecules of the iron return to their helter-skelter position and the piece loses most, but not all, of its magnetism. What remains is called residual magnetism. Soft iron is used because it can be most readily magnetized and demagnetized.

Assessment and Review:

1. Have the students repeat the procedure with a larger nail.
2. Which electromagnet is stronger?
3. Students can observe and hypothesize about what might possible create a stronger electro magnet.
4. You can expand on this activity by using a permanent magnet to discover the north and south poles of the electromagnet. Also, additional batteries can be taped together to see if more electrical voltage will increase the strength of the electromagnet.

Science Activity 3.3 Factors That Affect Electromagnetism

Objective: To investigate the relationship between an electric current and a magnetic field.

Introduction:

A wire carrying an electric current produces a magnetic field in the area around its path. The French scientist Andre Ampere (1775 to 1836) discovered that coiled wire has a stronger magnetic effect than a straight wire. The number of coils have a definite effect on the magnetic field created by an electric current.

Materials:

- One 1.5-volt battery (dry-cell)
- 100 cm strip of insulated copper wire
- 30 cm strip of insulated copper wire
- A switch
- Compass
- Large iron nail approximately 10 cm
- 15 small paper clips
- A small knife or scissors
- A pencil

Procedures:

1. With the knife or scissors, strip about 5 cm of insulation from the ends of each piece of copper wire. Be careful not to cut the wire.
2. Wind the insulated part of the longer wire around the pencil. Make ten turns.
3. Attach one free end of the coiled wire to the positive (+) post of the battery. Attach the other end of this coiled wire to one side of the open switch. Attach the shorter piece of wire to the other side of the switch and to the negative (-) post of the battery.
4. Remove the pencil from the center of the coil. Place the compass above the coil. Close the switch and record what you see. Open the switch.
5. Hold the coil about 1 cm above the paper clips. Close the switch. Count the number of paper clips your electromagnets attracts. Record your results in the data table. Repeat this procedure two more times. Record results in the data table for trial 2 and trial 3. Compute and record the average of the three trials.
6. Place the pencil back inside the coil and make 20 more turns of wire on the coil. There should now be 30 coils. Repeat step 5. Record your results and compute the average.
7. Uncoil the wire. Now wind it around the iron nail instead of the pencil.
   Make 10 turns. Leave the nail inside the coil.

8. With the nail inside the coil, repeat step 5. Observe how many paper clips the electromag net picks up. Record this in the appropriate column next to trial 1. Make two more trials: record the results and calculate the average.
9. Wind 20 more turns of wire around the nail. Repeat step 5. Do three trials altogether. Record your results and compute the average.

Assessment and Review:

1. What purpose did the compass serve?
2. How did the number of coils in the wire affect the number of paper clips the coil was able to attract?
3. How did the presence of the iron nail in the coil affect the coil's magnetic field?
4. Identify two ways that you could strengthen the magnetic field around a coil carrying a current.

Science Activity 3.4 How Are Magnetism And Electricity Related?

Objective: To show the relationship between magnetism and electricity

Materials:
- 30 cm length of insulated copper wire, stripped 1 cm at ends (25-30 gauge).
- 10 cm length of insulated copper wire, stripped 1 cm at ends (25-30 gauge)
- Bits of steel wool from soapless steel wool pads or iron filings.
- Bits of paper (confetti-size)
- Two 6-volt lantern batteries (to be connected in series)

Procedures:
1. Sprinkle some iron filings on a sheet of paper.
2. Use the 10 cm length of wire to connect the positive terminal of one battery to the negative terminal of the other battery. Use the 30 cm length of wire to connect the other terminals of the batteries. (See diagram above.)
3. Holding the insulated part of the 30 cm wire, place the exposed copper center of the wire on the iron filings. Make sure the copper wire touches the filings. Slowly lift the wire.
4. Observe and record what happens.

Assessment and Review:
1. Predict what will happen if one end of the wire is disconnected from the battery.
2. Try disconnecting one wire from the battery to see what actually does happen.
3. Experiment with small bits of paper substituted for the iron filings.

4. Compare the results of the experiment with the iron filings with the experiment with the bits of paper.
5. From your experiments, what can you infer about the relationship between electricity and magnetism?